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A genetic approach to the scheduling of preventive maintenance tasks on a single product manufacturing production line

G. Cavory, R. Dupas*, G. Goncalves

Laboratoire en Organisation et Gestion de la Production, Faculté des Sciences Appliquées, University of Artois, F-62408 Béthune, France

Abstract

The present article deals with optimising the schedule of maintenance tasks of all the machines in a single product manufacturing production line. This study was made in the context of one machine assigned to one operator. This operator intervenes to change tools during a stoppage. Our goal is to increase the overall through-put of the line. We firstly formalised the problem and showed the difficulty of its analytical resolution. Then, we presented the software environment that enables the resolution of this problem: it is made up of a simulator of the production line and an optimiser using the genetic algorithms. Our approach to the scheduling of maintenance tasks was validated upon an actual production line of car engines. We focused our study on the setting of parameters of a genetic algorithm. We proceeded with a systematic approach inspired by the Taguchi method to find the best combination of levels for each studied parameter and performed a statistical confirmation of the results. Finally we validated the genetic approach as against naive optimisation. © 2001 Elsevier Science B.V. All rights reserved.

Keywords: Scheduling; Genetic algorithm; Discrete event systems simulation; Single product; Tools changes

1. Introduction

The domain of this study is the manufacturing production systems. More precisely, the line concerned is a single product mass production line. This line, as in Fig. 1, of a succession of machines alternating with buffers of pieces.

Each machine unit in this line is characterised as follows.

- The machines perform multiple operations, the succession of which is a line of type "transfer". As the line is balanced, the machines have equal duration cycles.
- The preventive maintenance tasks on these machines are realised by the operator. Each task occupies a certain amount of the operator's time. The number of maintenance tasks varies according to the machine.

There are two sorts of preventive maintenance operations:

- a tool change, necessitating a machine stoppage;
- a control, which does not necessitate a machine stoppage.

This work has been done in the following framework.

* Corresponding author. Tel.: + 33-321028761; fax: + 33-321028758.

E-mail address: dupas@iut-gtr.univ-artois.fr (R. Dupas).

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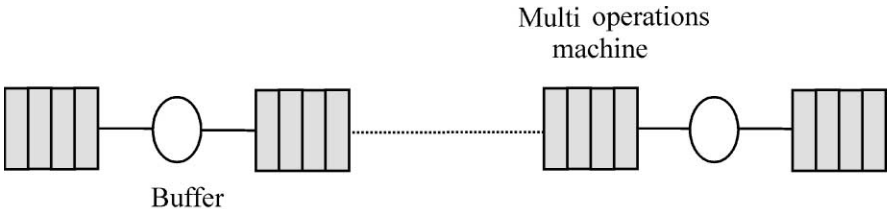

Fig. 1. Manufacturing line.

Hypothesis 1. The assignment of operators to the machine is restricted to the case of one machine assigned to one operator: an operator is always present on each machine of the line.

Hypothesis 2. The changing of tools is more critical than the controls; since, through the stoppage of the machine, it has a negative influence on the number of pieces produced. In a normal situation, the controls are done in "masked time", i.e. without stopping the machine. Consequently these controls are not considered in this study.

The subject of this article is the scheduling of preventive maintenance tasks, namely the changing of tools on all the machines in the line. Anderson et al. [1] have presented a review of scheduling in production machines or in computers. They are academic scheduling problems. Here in this article, we aim to address the industrial problem defined in Section 2.

2. Scheduling maintenance tasks on the machines of the line

In this section the maintenance tasks will be described. In the second part, the evolution of these tasks in the course of time will be analysed; then the problem of scheduling these tasks will be described.

2.1. Definition of the maintenance tasks

We consider the maintenance tasks that are of the preventive type. They are defined as follows for the set of machines that form the line.

Let T_L be the set of tasks:

$$T_L = t_{i,k} \mid i \in [1, w], k \in [1, n_i],$$

where $t_{i,k}$ is the task k on machine i of the line, n_i the total number of tasks on the machine$i$, w the total number of machines in line, and $N = \sum_{i=1}^{w} n_i$ the cardinality (T_L).

These tasks occur cyclically after a fixed time of machining. So each task has multiple occurrences in the course of production. They are defined by the following three parameters.

The first parameter of a task is the period of running after which the task is launched. It depends on the wearing out of tools during the machining. It can be naturally expressed in number of pieces finished and is defined by the parameter $b^{\sim}(t_{i,k})$ for the task $t_{i,k}$.

The second parameter is the shortened running time before the launching of the first occurrence of a task. The first occurrence is specific in that it can be selected before production starts. It is defined by the parameter $f^{\sim}(t_{i,k})$ for the task $t_{i,k}$. We have the following constraint on $f^{\sim}(t_{i,k})$: $f^{\sim}(t_{i,k}) < b^{\sim}(t_{i,k})$. This parameter corresponds to a premature change of tools in the starting phase of manufacturing.

The last parameter is the task duration expressed in time units. It is defined by the parameter $d(t_{i,k})$ for task $t_{i,k}$. In order to express the three parameters in the same unit, an approximation in the number of pieces produced is worked out to express the duration defined by parameter $d^{\sim}(t_{i,k})$. This approximation is based on machine cycle time "Tc", which is the span of time between the output of two consecutive pieces. The task duration is precisely defined by the parameter $d^{\sim}(t_{i,k}) = \langle d(t_{i,k})/\mathrm{Tc}_i \rangle$ with the following notation: $\langle x \rangle$, the